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# REASONS FOR VARIATIONS IN GLASS MELT DIATHERMANCY IN AN OPERATING TANK FURNACE

**A. B. Atkarskaya[1] and V. I. Kiyan[1]**

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Taking into account variations in glass melt diathermancy, nonstandard situations arising in operating a multi-ton tank furnace are considered. It is demonstrated that an increase in the quantity of introduced cullet, as well as a decrease or a temporary suspension in glass production, lowers the glass melt diathermancy.

For successful operation of multi-ton glass melting systems, all glass melting parameters should be stabilized, since any deviation from the optimum conditions causes unpredictable and often irreversible consequences. As the result, the glass quality is impaired and the furnace campaign is shortened.

The most common disturbances of the optimum technological process include fluctuations in the glass batch/cullet ratio toward a higher share of the latter (instead of the recommended 20 – 30%), a decrease in the glass output (both factors caused by a shortage of materials), hot repair, and liquidation of emergency situations.

The purpose of the present study is to estimated the variations in glass melt diathermancy caused by violations of the stable process of producing clear thermally polished sheet glass.

For a quantitative estimate of glass diathermancy, we used the diathermancy index (DI) proposed by the authors in [1], which is numerically equal to

$$\mathrm{DI} = 10^{-1}\,\tau_{1100}\,,$$

where $\tau_{1100}$ is the light transmission, %, of a glass sample 10 mm thick with the wavelength 1100 nm.

It is known that bivalent iron has the absorption band near 1100 nm [2]; therefore, the diathermancy index is proportional to the absolute weight content of FeO in glass. The higher this content, the lower the diathermancy index value and the worse the diathermancy of glass.

In order to improve diathermancy, the FeO content in glass should be maintained at the optimum relatively low level. This can be accomplished by decreasing the total content of iron in glass through using purer (with respect to iron impurities) materials, by sand flotation, cullet washing, and magnetic separation used at the final stages of preparation and mixing of batch materials.

Table 1 indicates the relationship between the glass melt diathermancy index and the content of iron in dolomite supplied from various deposits in scheduled replacement of raw materials.

As the iron content in dolomite grows from 0.06 to 0.41% (here and elsewhere weight content is indicated), the amount of total and bivalent iron in the glass increases, respectively, from 0.073 to 0.180 and from 0.022 to 0.062%. At the same time, the diathermancy index decreases by the factor 1.9 (from 6.96 to 3.61), and the maximum melting temperature, accordingly, grows (from 1520 to 1560°C).

Thus, deterioration of material quality with respect to the iron content can increase the amount of FeO in glass, which decreases the glass melt diathermancy and requires a higher melting temperature.

It is known that iron exists in glass in two valence states: Fe(II) and Fe(III) [2], whose ratio depends on several external and internal factors. Thus, an increase in the melting temperature, a decrease in the total content of iron in glass, and extension of the melting time cause a shift to the right in the

**TABLE 1**

| Sample | Weight content of iron, %: in dolomite $Fe_2O_3^*$ tot | in glass: $Fe_2O_3^*$ tot | in glass: $FeO^{**}$ | FeO share, % | Diathermancy index | Maximum melting temperature, °C |
|---|---|---|---|---|---|---|
| 1 | 0.060 | 0.073 | 0.022 | 32.4 | 6.96 | 1520 |
| 2 | 0.199 | 0.085 | 0.028 | 36.7 | 6.31 | 1530 |
| 3 | 0.410 | 0.180 | 0.062 | 38.4 | 3.61 | 1560 |

* Total iron content converted to $Fe_2O_3$ determined by the chemical-analytical method.

** FeO content determined by the spectrophotometric method.

[1] K. T. Bondarev Avtosteklo Plant, Konstantinovka, Ukraine.

TABLE 2

| Sample | Weighty content of iron in glass, %, in the form of | | FeO share, % | Quantity of introduced cullet, % | Diathermancy index | Decrease in the yield of acceptable product, % | Notes |
|---|---|---|---|---|---|---|---|
| | total iron converted to $Fe_2O_3$ | FeO | | | | | |
| 1 | 0.146 | 0.045 | 34 | 39 | 4.8 | 6.1 | – |
| 2 | 0.115 | 0.049 | 48 | 40 | 4.5 | 30.7 | – |
| 3 | 0.103 | 0.039 | 42 | 44 | 5.3 | 7.1 | – |
| 4 | 0.095 | 0.051 | 59 | 44 | 4.3 | 21.4 | – |
| 5 | 0.102 | 0.036 | 40 | 37 | 5.5 | 6.0 | – |
| 6 | 0.101 | 0.039 | 44 | 44 | 5.3 | 17.7 | – |
| 7 | 0.138 | 0.056 | 45 | 51 | 3.8 | 5.5 | – |
| 8 | 0.136 | 0.059 | 48 | 58 | 3.7 | 28.1 | – |
| 9 | 0.138 | 0.056 | 45 | 51 | 3.8 | 6.0 | Molding rate, 160 m/h |
| 10 | 0.136 | 0.066 | 53 | 49 | 3.4 | 7.4 | The same, 102 m/h |
| 11 | 0.126 | 0.038 | 34 | 40 | 5.4 | – | Hot repair |
| 12 | 0.127 | 0.042 | 37 | 41 | 5.0 | – | The same |
| 13 | 0.090 | 0.045 | 57 | 42 | 4.8 | – | Emergency situation |
| 14 | 0.100 | 0.055 | 61 | 41 | 4.1 | – | The same |

equilibrium Fe(III) ⇄ Fe(II), and clarifying additives (sodium sulfate, arsenic oxide) cause a shift to the left [3, 4].

The state of the Fe(III) ⇄ Fe(II) equilibrium can be quantitatively estimated from the change in the content of bivalent iron [5]:

$$d_{FeO} = 100\,\frac{m\text{FeO}}{n\text{Fe}_{tot}},$$

where $m$FeO and $n\text{Fe}_{tot}$ are the weight contents of bivalent and total iron in glass, %, respectively, determined by spectrophotometric and chemical-spectral methods.

Table 2 correlates the diathermancy index values with certain parameters and characteristics of the technology of thermally polished sheet glass production. It can be seen that an increase in the total content of iron in glass from 0.115 to 0.146% leads to a decrease in the FeO quantity from 0.049 to 0.045 and an increase in the diathermancy (samples 1 and 2). The same regularity is observed in samples 3 and 4 (Table 2).

The described results disagree with the data in Table 1. Of the two factors with opposite effects on the Fe(III) ⇄ Fe(II) equilibrium, i.e., an increased content of iron, on the one hand, and an increase in the maximum melting temperature, on the other hand, the second factor is predominant. Therefore, the share of FeO and, accordingly, the absolute content of FeO grow, whereas the diathermancy of glass regularly deteriorates.

The analysis of samples 1, 2 and 3, 4 (Table 2) indicates that the Fe(III) ⇄ Fe(II) equilibrium is influenced only by the alteration in the total amount of iron in glass. Therefore, as the $Fe_2O_3$ content in the glass melt increases, the FeO share and absolute content decreases, and diathermancy improves.

In accordance with the technological requirements on the operation of a large glass-melting furnace, the ratio between the glass batch and cullet charged into the furnace should be constant and close to 80 : 20%. This does not always occur in reality. Emergency situations and difficulties related to supply of material force manufacturers to increase the quantity of the introduced cullet. The analysis of samples 5, 6 and 7, 8 (Table 2) indicates poorer diathermancy in the glass melted with an increased quantity of cullet. The decrease in the diathermancy index in all the considered cases is related to an increased total content of iron caused by an increased share of FeO.

This means that an increase quantity of introduced cullet shifts the Fe(III) ⇄ Fe(II) equilibrium to the right. The latter occurs, on the one hand, due to a decreased amount of oxidizer, i.e., sodium sulfate introduced into the system, as the share of the batch decreases. On the other hand, cullet represents fully formed glass with a fixed total amount of iron and an established equilibrium Fe(III) ⇄ Fe(II). When loaded into the furnace, the cullet is subjected to another melting cycle, and its content of FeO should increase. All this lowers the diathermancy of the glass that is melted with an increased cullet content.

In operating float systems, situations may occur in which, due to a shortage of material, emergency situations, or hot repair, the output of glass decreases or becomes suspended for a certain period. In such cases the glass melt remains inside the furnace longer than usual. In other words, the melting duration increases, which contributes to an increased FeO share in the glass. Therefore, it can be expected that the share of FeO, the total iron content, and the diathermancy of glass produced before and after the specified situations are likely to be different.

An increase in the molding rate of the glass band, i.e., a decrease in the output (Table 2, samples 9 and 10) from 160 to 102 m/h, as expected, increase the share and the total content of bivalent iron from 45 to 53 and from 0.056 to 0.066%, respectively. The diathermancy index regularly decreases from 3.8 to 3.4.

The glass produced after emergency or scheduled stops (Table 2, samples 11, 12 and 13, 14) as well has poorer diathermancy due to the regular increase in the share and the total content of bivalent iron, compared to the glass produced before the stop.

Thus, any situation involving a decrease or a stop in glass production impairs its diathermancy.

It is known that the surface glass layers in the melting zone of the tank furnace are hotter than the bottom layers, whereas in the chilling and working zones the situation is the opposite, and the temperature gradient is closely related to diathermancy [1]. Therefore, with annealing conditions constant, glass with a high diathermancy index will probably be more poorly annealed than glass with a low diathermancy index. This will undoubtedly impair the cutting of the glass band and reduce the yield of acceptable product.

The following conclusions can be drawn from the above data:

– a decrease in the diathermancy index of clear technical glass requires an increased melting temperature;

– an increase in the total iron content in glass can result either in deterioration or in improvement of the diathermancy of glass;

– an increase in the share of introduced cullet, a decrease in the molding rate, and emergency situations accompanied by a suspension of glass production lead to deterioration of the glass diathermancy;

– a decrease in glass diathermancy results in a decreased yield of acceptable product.

## REFERENCES


1. Yu. A. Guloyan, *The Efficiency of Technological Processes in Production of Glass Articles* [in Russian], Legkaya Prom-st', Moscow (1982).
2. L. I. Demkina, *Physicochemical Principles of Optical Glass Production* [in Russian], Khimiya, Leningrad (1976).
3. A. Paul and R. W. Douglas, "Ferrous-ferric equilibrium in binary alkali silicate glasses," *Phys. Chem. Glasses*, **6**(6), 207 – 211 (1965).
4. *Chemical Technology of Glass and Glass Ceramics* [in Russian], Stroiizdat, Moscow (1983).
5. V. I. Kiyan, É. K. Polokhlivets, P. A. Krivoruchko, and A. B. Atkarskaya, "Redox potential of the glass melt in a continuous technological process," *Steklo Keram.*, No. 11, 10 – 12 (1999).